# ENSO CYCLE AND PURSE SEINE TUNA FISHERIES IN THE INDIAN OCEAN WITH EMPHASIS ON THE 1998-1999 LA NINA

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## ABSTRACT

*The paper WPTT-00-17 analyses the effects of the recent La Niña event on the dynamics of the purse seine fishery in the Indian Ocean. This paper completes a similar analysis made after the 1997-98 El Niño, that was presented during the 1999 IOTC working party (paper WPTT….). These two events form opposite phases of the ENSO cycle; however, a La Niña event does not necessarily follow a El Niño event. The occurrence of both events within the last 3 years was therefore a good opportunity to compare the fishing patterns. In the area 0° - 10°S, that encompasses a large fraction of the purse seine fishing grounds, El Niño causes positive SST anomalies and a deepening of the thermocline in the Western equatorial area, and negative SST anomalies associated to a reduced mixed layer in the East. During La Niña, the equatorial area does not exhibit significant anomalies, and the environmental pattern is rather similar to the normal conditions. The negative SST anomalies associated to La Niña are only observed in the south tropical region (20°S to 25°S), that is out of the surface fishery area. The outstanding feature of the last three years is an extension of the fishery area out to 100°E during the full development of El Niño, and a quick return to the classical western fishing grounds during La Niña. The CPUE indices for unassociated schools exhibited two lows, in 1992 and 1998, that match with strong warming events in the Indian Ocean. Conversely, CPUE values increased again in association with La Niña. It is likely than these indices reflect more changes in catchability than changes in abundance. Along the time series 1992-1999, the spatial dynamics of the fishery can be fairly well explained by some climatic indicators, such as the zonal wind stress and the sea level height deviation. These parameters could be integrated in population dynamics models incorporating habitat indices.*

## INTRODUCTION

The period 1997-2000 has been characterised by a very strong ENSO (El Niño-Southern Oscillation) cycle which has been well monitored by meteorologists and oceanographers. The numerous observations that are now available from various platforms (from satellite to vessels and buoys) enable a near-real time follow up of the anomalies affecting the global ocean and atmosphere systems.

ENSO is a quasi-periodic disturbance of the climate system which occurs every few years (3 to 7 years) and lasts approximately one year. The disturbance consists of a warm (El Niflo) and cold (La Nina) phase, but the warm phase tends to have more societal impacts than the cold (Glantz 1996). Its centre of action is located in the tropical Pacific, but its influence extends well beyond the Pacific, through teleconnections between ocean basins.

During the last 25 years, there has been twice as many El Nifto events than La Nina events, and La Nina does not necessarily follow every El Nifio. Some authors suggest that the global warming favours the development of warm events (Fedorov and Philander 2000). Five La Nina events have been recorded since the 1970s: in 1973, 1975, 1988-89, 1995-96 and 1998-99. Another observation is that La Nina events have a lesser amplitude than El Niño events: the largest warm event years (1982, 1997) had maximum values greater than 3-4 standard deviations while the cold events years peaked around 2 standard deviations. The largest SST (sea surface temperature) anomalies form in the eastern Pacific, in the "cold tongue" area:

during La Nina, the trade winds regime is stronger than normal, resulting in an increased equatorial upwelling and colder waters. Conversely, during El Niño, a positive SST anomaly propagates eastward along the equatorial Pacific. Indian and Atlantic Oceans are also affected (Tourre and White 1995, Nicholson 1997, Glantz 1996), making the El Nifto, La Nina and the Southern Oscillation a global concern (Philander 1990).

Oceanic fisheries are concerned by El Niño and La Nina events. In this paper, attention is put on the equatorial regions to describe the impacts of the recent La Nina on the purse seine tuna fisheries in the Indian Ocean.

## OCEANOGRAPHIC IMPACTS OF THE ENSO CYCLE IN THE INDIAN OCEAN

On the overall, the SST and sea-level anomaly patterns in the Indian Ocean are the mirror-image of those occurring in the Pacific. Larkin and Harrison (1998) demonstrate the phase coherence between both oceans from an analysis based on 10 warm events and 9 cold events recorded since the World

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War 2. From this analysis, they also suggest a typical scenario for the Indian Ocean, where the SST anomalies are stronger (negative) during La Nifta than during El Nub (positive) events.

A global picture of SST patterns during the ENSO cycle is given in Figure 1. As mentioned earlier, the Central equatorial Pacific exhibits the highest variability. The Indian Ocean is affected by positive SST anomalies in a large part of the southern hemisphere (including the equatorial region) during the warm phase, while the negative anomalies of the cold phase are primarily located in the Central southern tropical region.

The longitude-time diagram shown in Figure 2 gives evidence of dominant warm anomalies in the equatorial area (5°S) associated with fluctuations of the SOI (Southern Oscillation Index). The 1998 El Nifio was the strongest ever recorded in the Indian Ocean, with positive anomalies as high as 2.5°C above normal that were observed across the entire basin. Since the early 80s in the Indian Ocean, there is a quasi quadriennal cycle with warm events appearing during the winters 1982-83, 1987-88, 1991-92, 1995-96 and 1997-98. The cold events are scarce and not as clear as the warm events. The SST anomalies develop mainly on the western boundary (1984, 1986, 1992, 1997). On the eastern boundary, strong cold anomalies can occur prior to the development of a warm event, like in 1994 and 1997. The eastern cold anomaly corresponds to a rising of the thermocline slope that is caused by stronger than normal easterlies.

The relationship between the SOl and the Indian Ocean SST anomalies at the equator is not relevant in all cases. While warm events are linked to low SOI values, there is no relationship between high SOI values (depicting La Nina) and cold anomalies. In particular, the strong 1999 La Nifta was not detectable along the equator, where normal conditions prevailed from mid-1998. Conversely, significant SST negative anomalies were observed between 20°S-25°S and 70°E-100°E (not shown). This pattern is in agreement with the global description shown in Figure 1.

The SST patterns also reflect changes occurring in the mixed layer. A good proxy for estimating the magnitude of the changes at the level of the thermocline is the sea height anomaly. This parameter is measured by satellite and represented by models (Fig. 3). The high SST anomaly observed in the west during the 1997-98 El Niño matches with a significant elevation of the sea level, reflecting a deepening of the thermodline at the same location. During the 1999 La Nina, there were some negative anomalies (i.e. shallow thermocline) in the north of 10°S, but this pattern is very similar to that recorded in January 2000, which is considered as a neutral situation. This would indicate that La Nifta events in the equatorial area are not very different from a normal situation, whereas El Nifto causes more drastic changes.

Impacts on the purse seine fisheiy

Data processing

The data used are the 1991-1999 purse seine catch and effort statistics aggregated by 1° square- fortnight bins. We only considered the three main species exploited by PS fleets, yellowfin, skipjack and bigeye. The catch data are split into associated (natural logs and FADs) and non-associated sets (school sets).

CPUE indices were computed in different areas by selecting the type of association. For instance, CPUEs on unassociated sets are calculated in the core distribution area for yellowfin, since this species is highly dominant in unassociated schools. The selected area (45°E-80°E/0°-10°S) is the place where individuals congregate for spawning, mainly from December to March. In this case, the fishing day is used as the unit effort. On the other hand, the bulk of the associated catches is made of skipjack, followed by juvenile yellowtin then bigeye. CPUEs are calculated in the Somali basin (45°E-65°S / 0°-15°N) using the successful set as the unit effort.

The method used to calculate CPUEs consists in choosing an effort threshold in the 1°square-fortnight bin, generally 2 fishing day for unassociated catches and or 2 positive sets for associated catches. The effort has to be greater or equal to the threshold value to compute catch rates in each bin. Then, the catch rates for each 1° square selected are averaged by fortnight and year. A seasonal profile is estimated by averaging each fortnight over the years. This profile is used to bound the season where the species is more abundant in the catch. Finally, CPUE indices are obtained for each year, by averaging the semi-monthly catch rates over the selected season.

### Distribution of purse seine catches

A series of maps showing the catch by species, quarter and 5° square is presented in figure 4 (associated catches) and figure 5 (unassociated catches), for 1997 - 1999.

The well-know pattern of associated catches in the Somali basin during quarters 3 and 4 has not changed significantly during these 3 years, although the catch reached some of the highest values in 1999, especially in the Somali area during the quarters 3 and 4.

The unassociated catches were very low in the western Indian Ocean in 1998,but returned to normal in 1999. The outstanding feature is the extension of the fishery to the East, from end of 1997 to March 1998.

### CPUE trends

CPUE indices for both types of sets are presented in figure 6, along with two climatic indicators, the SST anomaly and the SOl. The SST anomaly is the average anomaly at the equator from December to March, because this is the period when the Nino/Nina reach their highest intensity.

The CPUE indices for associated schools exhibits large variations, but no trend. The highest values were reached in 1995 and 1999, and there is not a direct link with the climatic indicators.

The CPUE indices for unassociated schools show an overall decline. Two lows occur in 1992 and 1998. They follow after a small lag, the lowest SOI values reached at the end of the years 1991 and 1997. Moreover, the low record of 1998 CPUEs matches with the highest SST anomaly ever recorded in the Indian Ocean, a result of the 1997-98 El Nifto.

## DISCUSSION

In the Indian Ocean, the impact caused by climatic anomalies on the purse seine tuna fishery seems more pronounced during the warm episodes (El Nino) than during the cold episodes. This is due to the fact that the La Nina effects mainly the south tropical area (south of 20°S), that is far from the surface fishery area. Along the equator, the recent La Nifla generated a quick return to normal hydrocimatic situation, with shallow thermocline in the west and deep thermocline in the east. This situation increased the catchabiity of the unassociated schools, what is shown by the CPUE indices. The associated schools CPUEs do not show a clear relationship with the environmental factors, the major reason being that we do not monitor well enough how to quantify the effort on logs and FADs.

However, it is possible to identify some indicators explaining the spatial dynamics of the fishery. As an example, we have plotted the gravity centre of the catches in the area 0°-10°S on the zonal (east-west) wind stress anomaly field (represented in a longitude-time diagram, Figure *7)*. The zonal wind stress (ZWS) can be used as a proxy of the depth of the habitat:

wind stress anomalies oriented to the east (red on figure *7)* tend to increase downwelling in the east and rise the thermocline in the west. Conversely, westward anomalies of ZWS (blue shades) deepen the thermocline in the west and reduce the volume of tuna habitat in the east, promoting tuna vulnerability to surface gears. The size of the fishery is therefore affected by those environmental features. Among other parameters, the sea level deviation provide another type of valuable information that can describe the potential volume of the habitat. These different indicators are spatially explicit and they can be easily integrated in population models using habitat indices.

## CONCLUSION

The response of the Indian Ocean to the ENSO variability is significant enough to affect the geographic distribution of the surface fisheries. The CPUE indices presented in this paper reflect more catchability than relative abundance of tuna populations. The outstanding change in the fishery is caused by the El Niño events, whilst La Nifta is very similar to a normal situation in the equatorial zone. The sudden rise of CPUE following the 1998-99 La Nina could be explained by a higher vulnerability due to a shallow thermocline. However, in addition to this positive effect, it is possible that the El Nino conditions of the previous year have significantly reduced the fishing mortality, resulting in a higher abundance available in the fishery during 1999. These conclusions are still provisional and should be re-analysed using spatial models incorporating environmental forcing.

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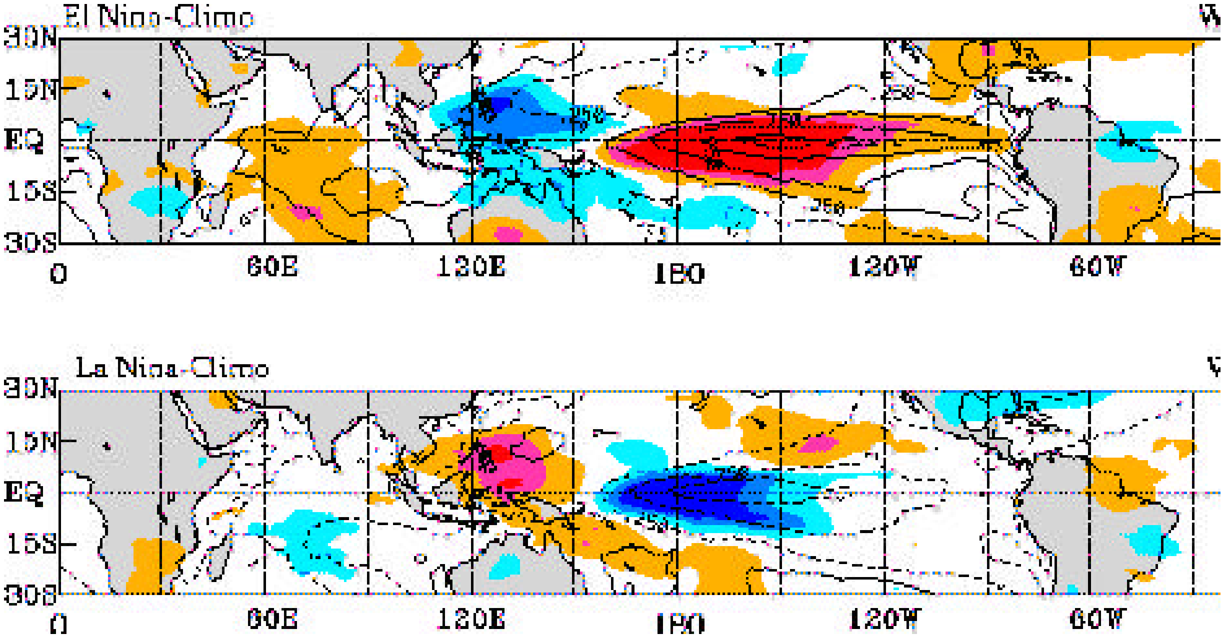


**Fig. 1** – Global patterns of SST anomalies, for warm (top) and cold (bottom) phases of the ENSO cycle.

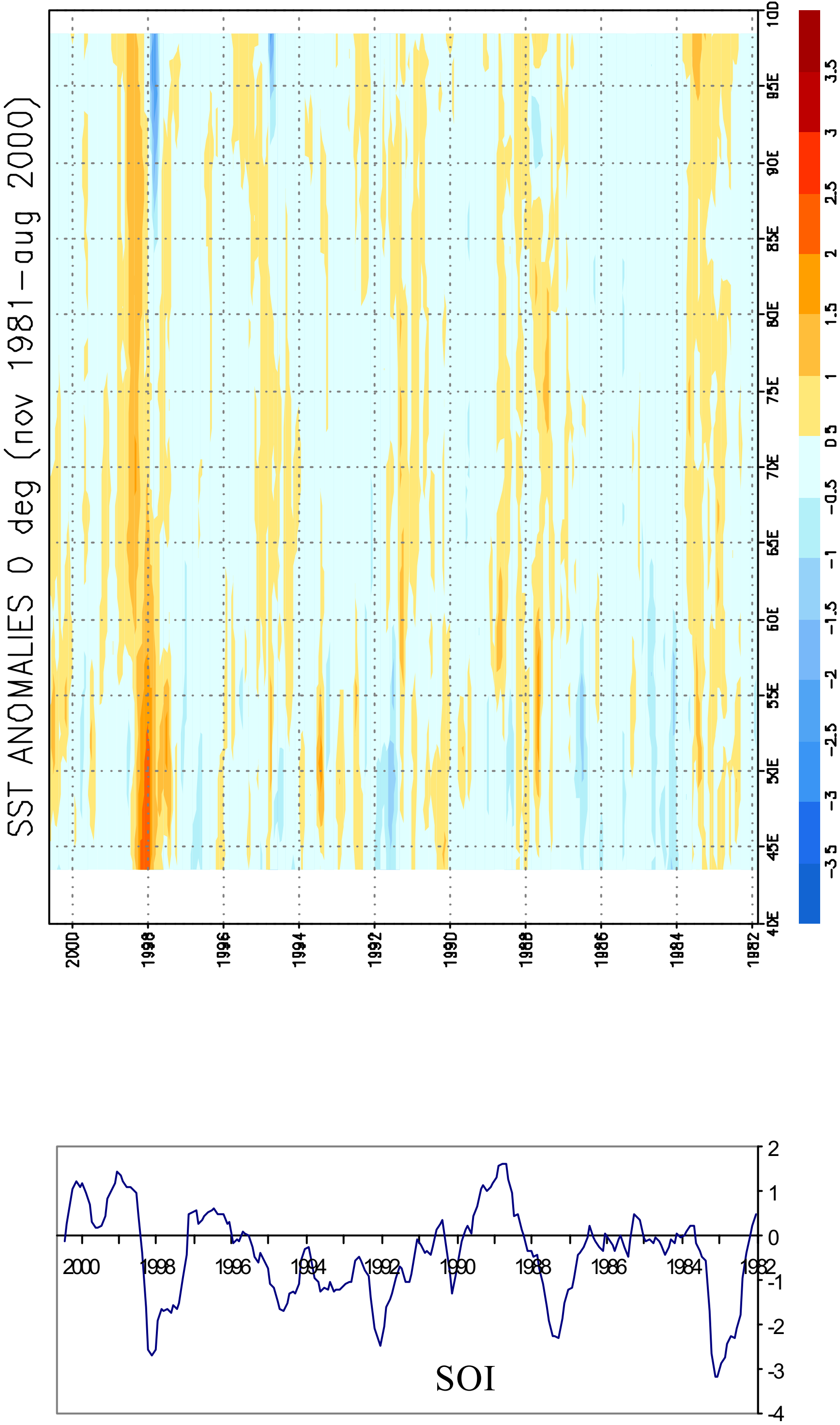
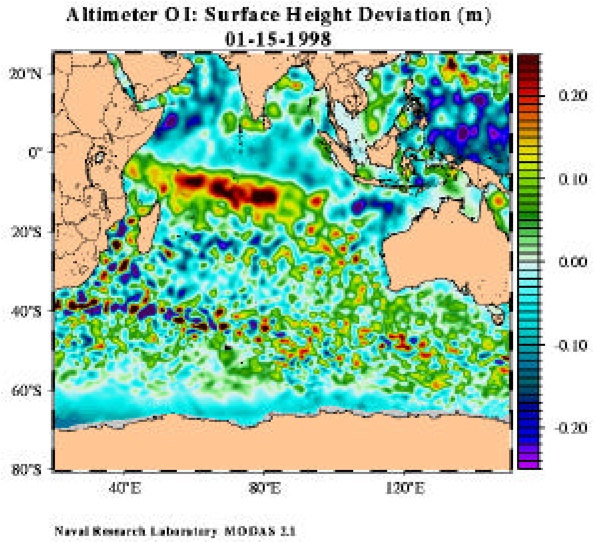
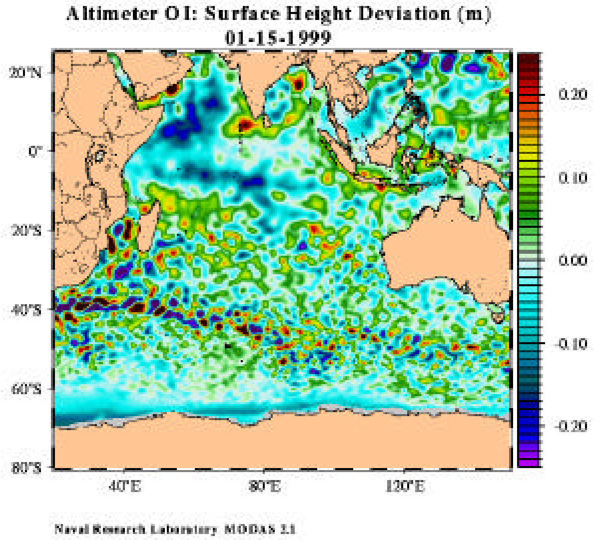


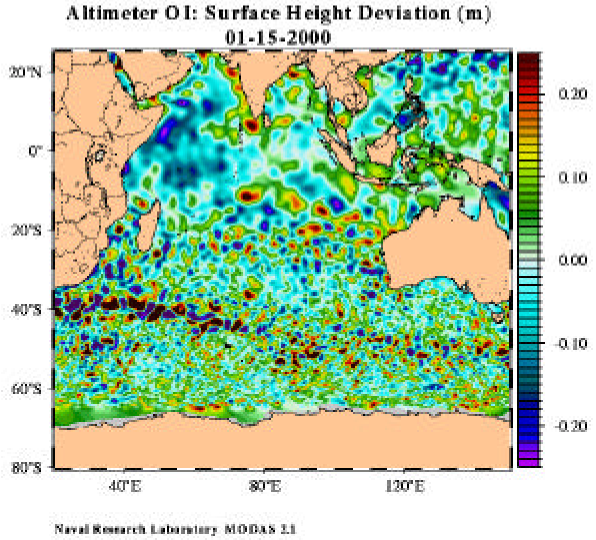
**Fig. 2 –** Hovmoller diagram (x axis: longitude 40°E-100°E; y axis: time Jan 1982-Aug 2000) of SST anomalies along the equator in the Indian Ocean (source: NCEP/NCAR CEDAS Reanalysis Project) (top) and the Southern Oscillation Index from January 1982 to August 2000 (bottom).



**EL NIÑO: warm phase**



**LA NIÑA: cold phase**



**NORMAL SITUATION**

**Fig. 3** – Surface height deviation (in metres) during two phases of the ENSO cycle and a normal situation, on January 15th of 1998, 1999 and 2000. The data were measured by TOPEX/POSEIDON and produced by the Naval Research Laboratory, Stennis Space Center)

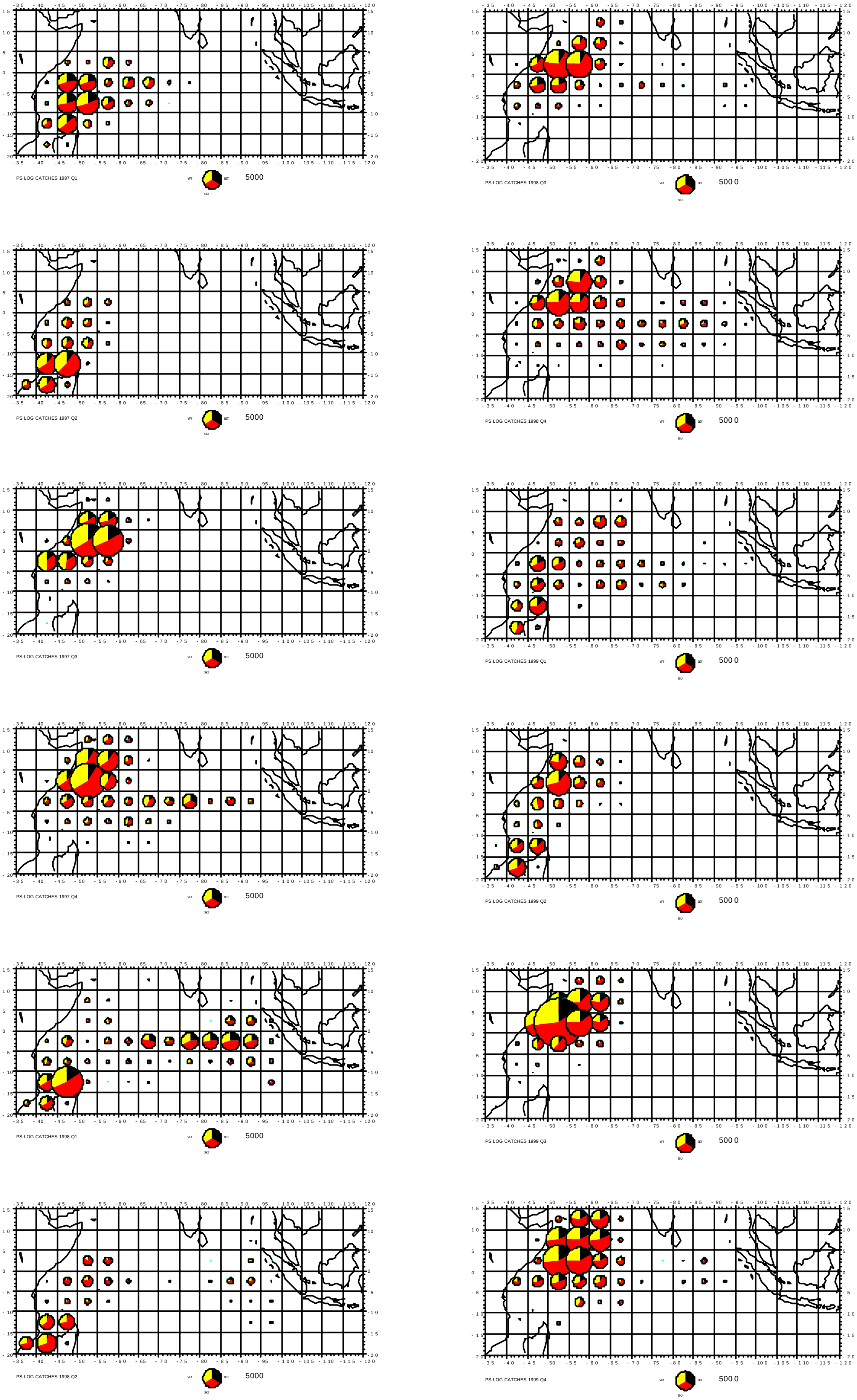


**Fig. 4** – Distribution of associated catches by quarter and 5° square (EU purse seiners including convenience flags). From 1997 quarter 1 (top left) to 1999 quarter 4 (bottom right). Species : yellowfin (light grey), skipjack (medium grey), bigeye (black).

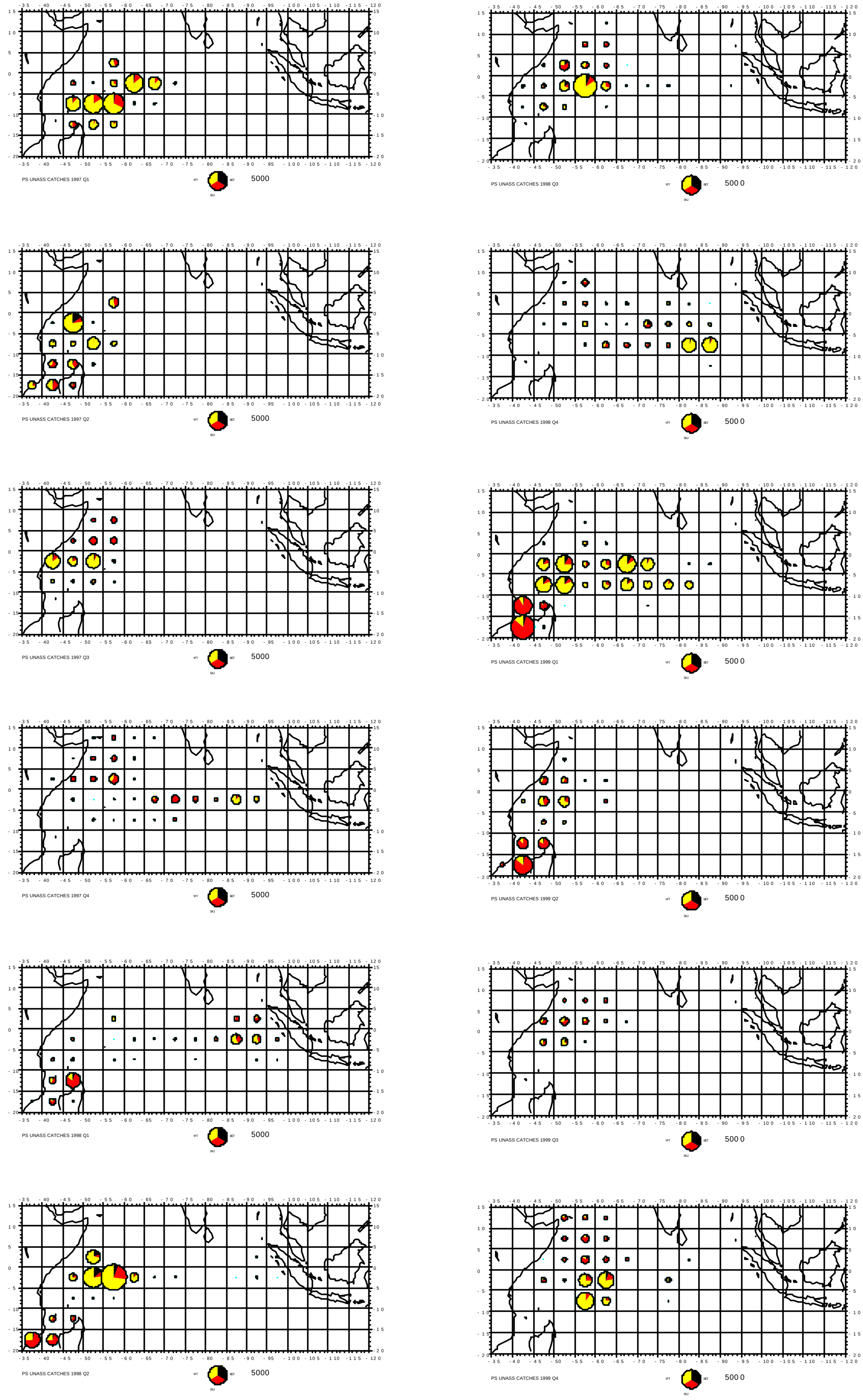


**Fig. 5** – Distribution of unassociated catches by quarter and 5° square (EU purse seiners including convenience flags). From 1997 quarter 1 (top left) to 1999 quarter 4 (bottom right). Species : yellowfin (light grey), skipjack (medium grey), bigeye (black).

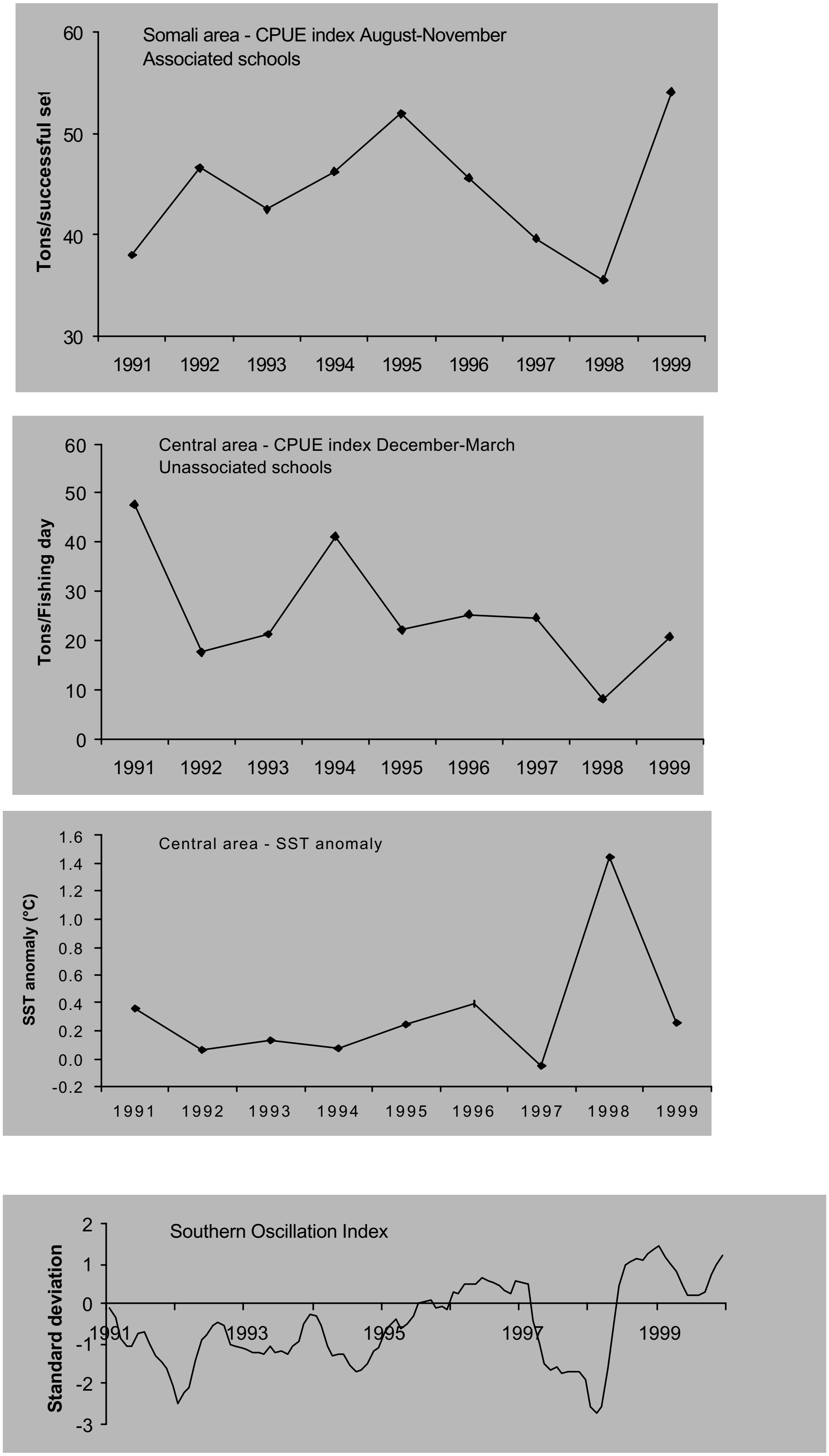


**Fig.6** – Plots of CPUE indices in the Somali area (45°E-65°E / 0°-15°N) and in the Central area(45°E-80°E / 0°-10°S) and climatic indicators, SST anomaly and the SOI.

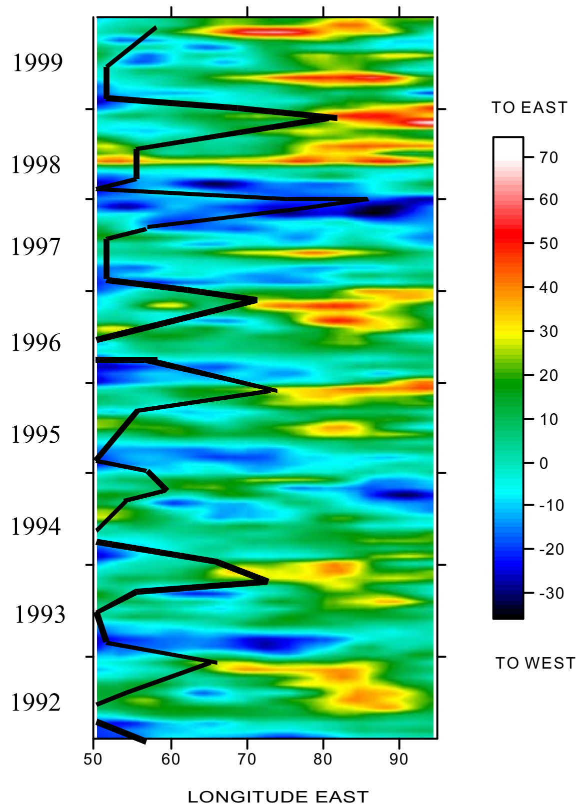


**Fig 7** - Hovmoller diagram (x axis: longitude 50°E-95°E; y axis: time Jan 1982-Dec 1999) of wind stress anomalies along the equator in the Indian Ocean (source: COAPS, Florida State University) (coloured background) and plot of the gravity centre of the unassociated catches (black line). The negative (positive) wind stress values denote an above normal westward (eastward) transport.